US008480052B2

(12) **United States Patent**
Taylor et al.

(10) **Patent No.: US 8,480,052 B2**
(45) **Date of Patent: Jul. 9, 2013**

(54) **VIBRATION ISOLATING DEVICE**

(75) Inventors: **Russell B. Taylor**, Melbourne, FL (US); **Jeremy Hutcherson**, Cape Canaveral, FL (US); **Vinson Loos**, Melbourne, FL (US)

(73) Assignee: **DRS Tactical Systems, Inc.**, Melbourne, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 63 days.

(21) Appl. No.: **13/004,107**

(22) Filed: **Jan. 11, 2011**

(65) **Prior Publication Data**

US 2012/0175489 A1 Jul. 12, 2012

(51) **Int. Cl.**
F16M 1/00 (2006.01)

(52) **U.S. Cl.**
USPC **248/638**; 248/563; 248/636; 248/610; 248/619; 720/651; 361/679.36; 361/679.35; 267/152; 267/153

(58) **Field of Classification Search**
USPC 248/563, 638, 610, 618, 619; 720/651; 361/679.36, 679.34; 267/136, 152, 153, 292
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,145,012	A	*	8/1964	Kfoury	248/568
3,323,764	A	*	6/1967	Johnson	267/140.4
3,762,694	A	*	10/1973	MacDonnell	267/3
4,251,045	A	*	2/1981	Meyerle	248/619
4,482,125	A	*	11/1984	Ziernicki	248/604
4,831,476	A	*	5/1989	Branc et al.	360/99.15
5,042,024	A	*	8/1991	Kurosawa et al.	720/651
5,100,096	A	*	3/1992	Mizuno et al.	248/638
5,207,081	A	*	5/1993	Fuse	68/23.1
5,379,990	A	*	1/1995	Ando et al.	267/34
5,456,454	A	*	10/1995	Schulz et al.	267/293
5,566,156	A	*	10/1996	Choi	720/634
5,663,943	A	*	9/1997	Yanagisawa et al.	720/651
5,667,202	A	*	9/1997	Gwinn	267/33
5,953,303	A	*	9/1999	Sugano et al.	720/651
6,129,445	A	*	10/2000	Landy	362/369
6,252,768	B1	*	6/2001	Lin	361/679.34
6,371,434	B1		4/2002	Becker et al.	
6,498,722	B1		12/2002	Stolz	
6,579,002	B1	*	6/2003	Bartick et al.	366/112
6,614,747	B2	*	9/2003	Imai et al.	720/693
7,016,189	B2	*	3/2006	Lin	361/679.34
7,079,380	B2	*	7/2006	Wubs	361/679.35
7,182,506	B2	*	2/2007	Schulz et al.	366/217
7,188,993	B1	*	3/2007	Howe et al.	366/111
7,251,131	B2		7/2007	Shah et al.	
7,267,313	B2	*	9/2007	Krzoska et al.	248/316.8
7,487,958	B2	*	2/2009	Wang	267/136
7,507,015	B2	*	3/2009	Wang	366/217
7,520,660	B2	*	4/2009	Schulz et al.	366/217

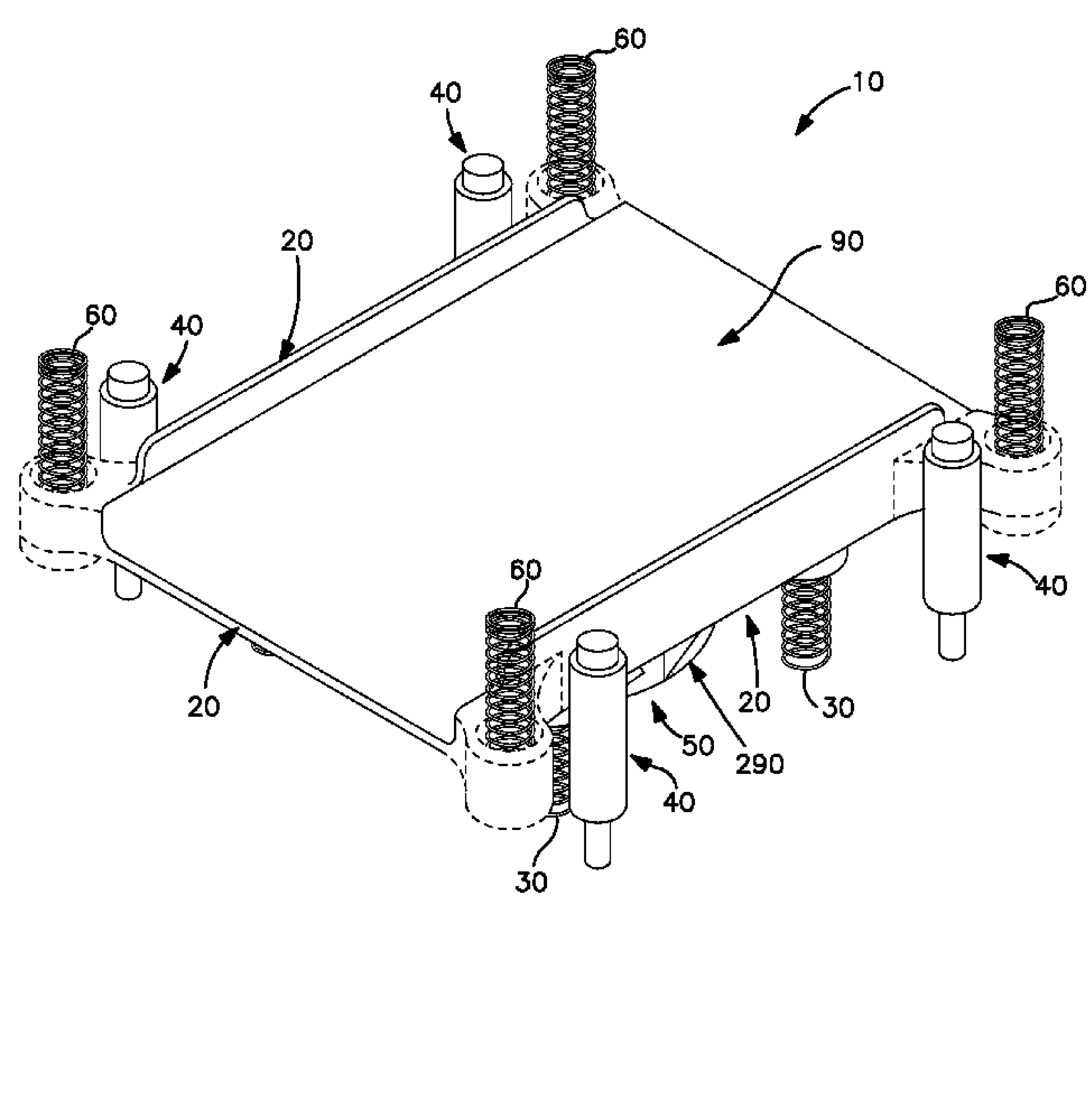
(Continued)

Primary Examiner — Terrell McKinnon
Assistant Examiner — Daniel J Breslin
(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend & Stockton LLP

(57) **ABSTRACT**

A vibration isolating device for isolating an object from at least one of vibration and shock from an external source. The vibration isolation device comprises such features as a mounting structure where the object is mounted to, at least a plurality of first springs coupled to the mounting structure to minimize coupling of the at least one vibration and shock to the object, and a shock stop. In addition, the device may include a plurality of stop pins that are separate from the mounting structure and arranged externally to the mounting structure. The stop pins can limit a displacement of the object when the at least one of vibration and shock exceeds a given level.

26 Claims, 7 Drawing Sheets



U.S. PATENT DOCUMENTS

7,837,380	B2 *	11/2010	Wang	366/217
7,856,916	B2 *	12/2010	Anderson	89/44.02
7,866,878	B2 *	1/2011	Howe et al.	366/108
2002/0053632	A1	5/2002	Becker et al.	
2003/0174464	A1 *	9/2003	Funawatari et al.	361/685
2003/0210519	A1	11/2003	Wubs	
2006/0023416	A1	2/2006	Chen	
2006/0254869	A1 *	11/2006	Wang	188/378
2006/0255517	A1	11/2006	Lee	
2008/0239654	A1	10/2008	Bisson	
2010/0051778	A1	3/2010	Wu	

* cited by examiner

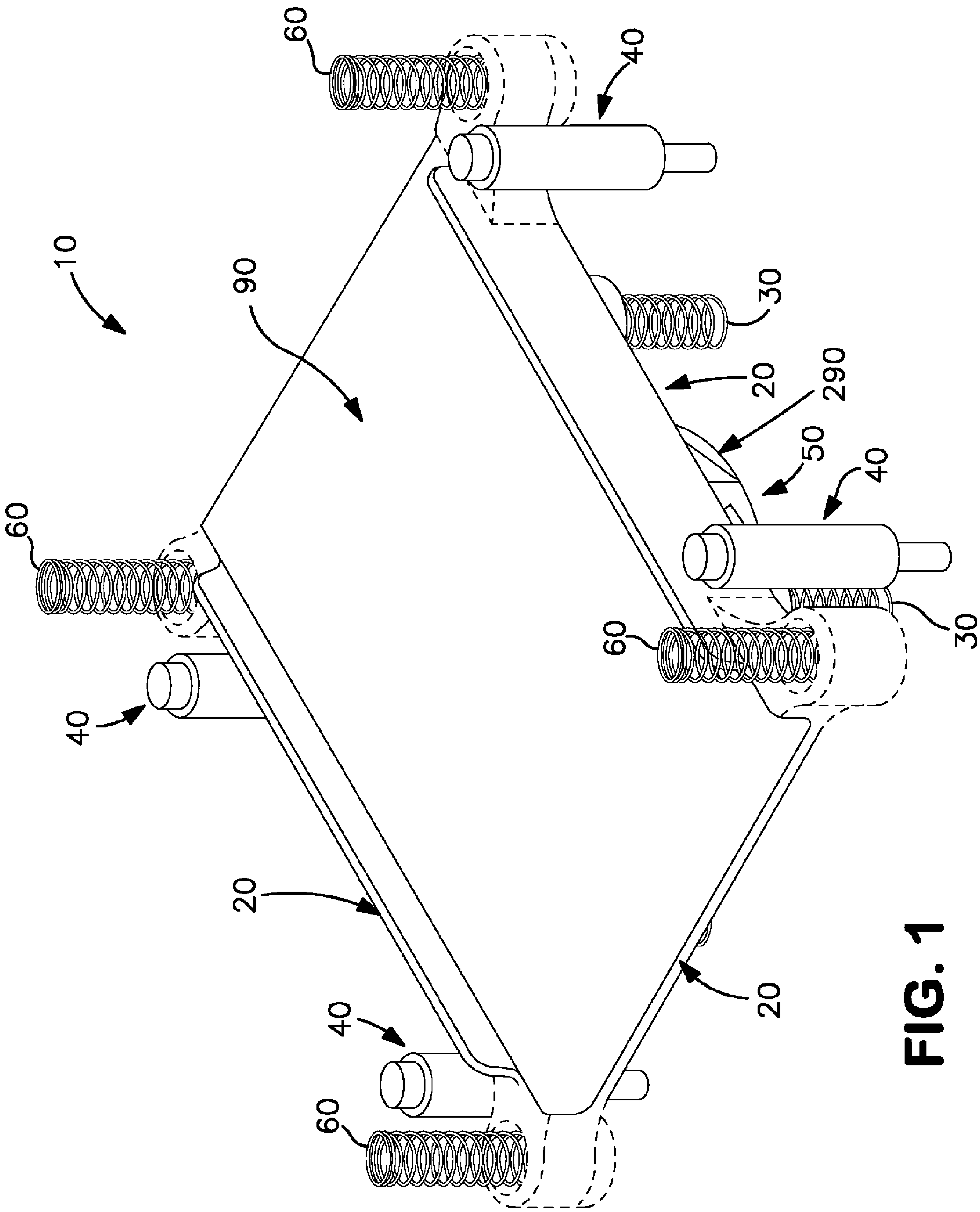


FIG. 1

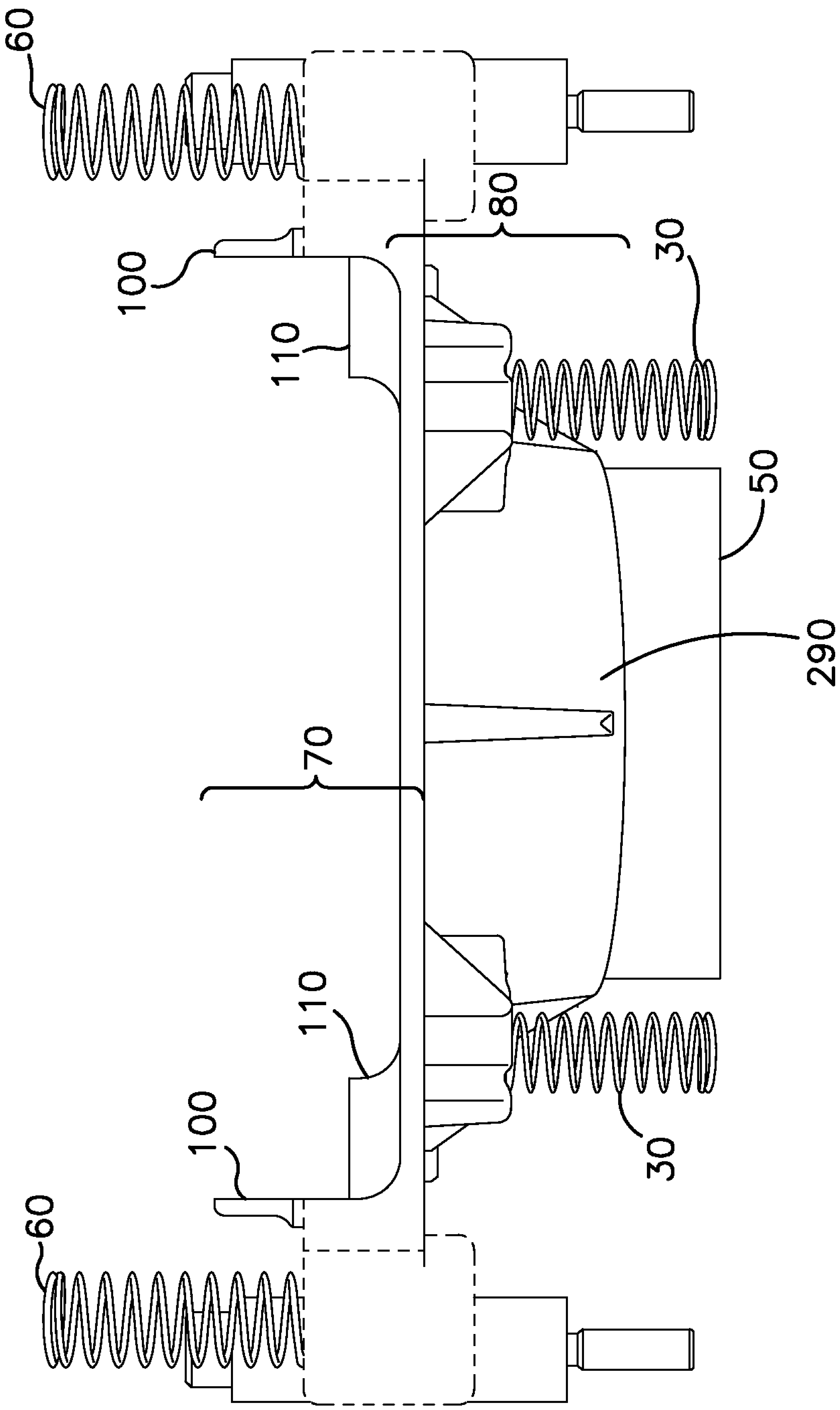


FIG. 2

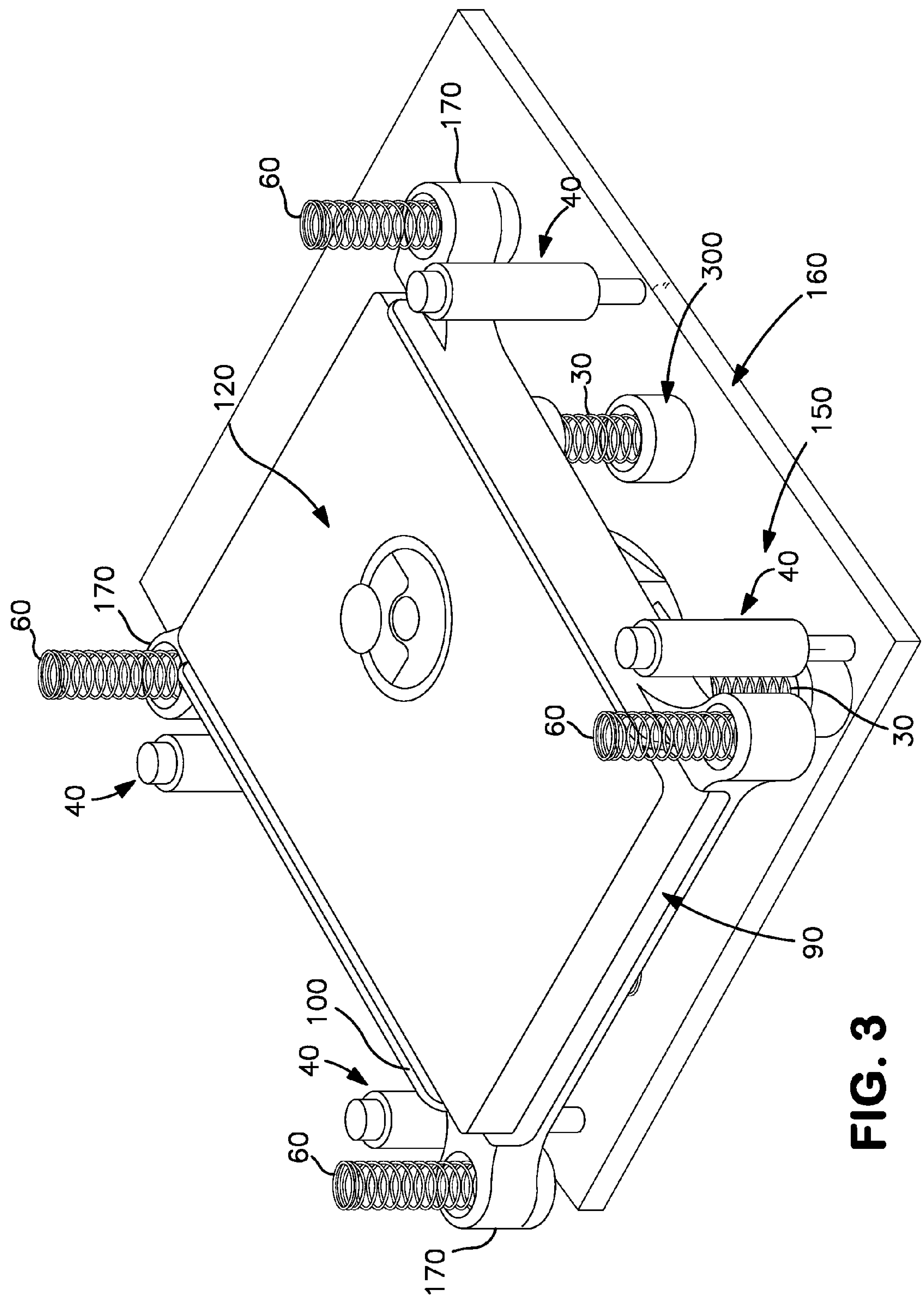


FIG. 3

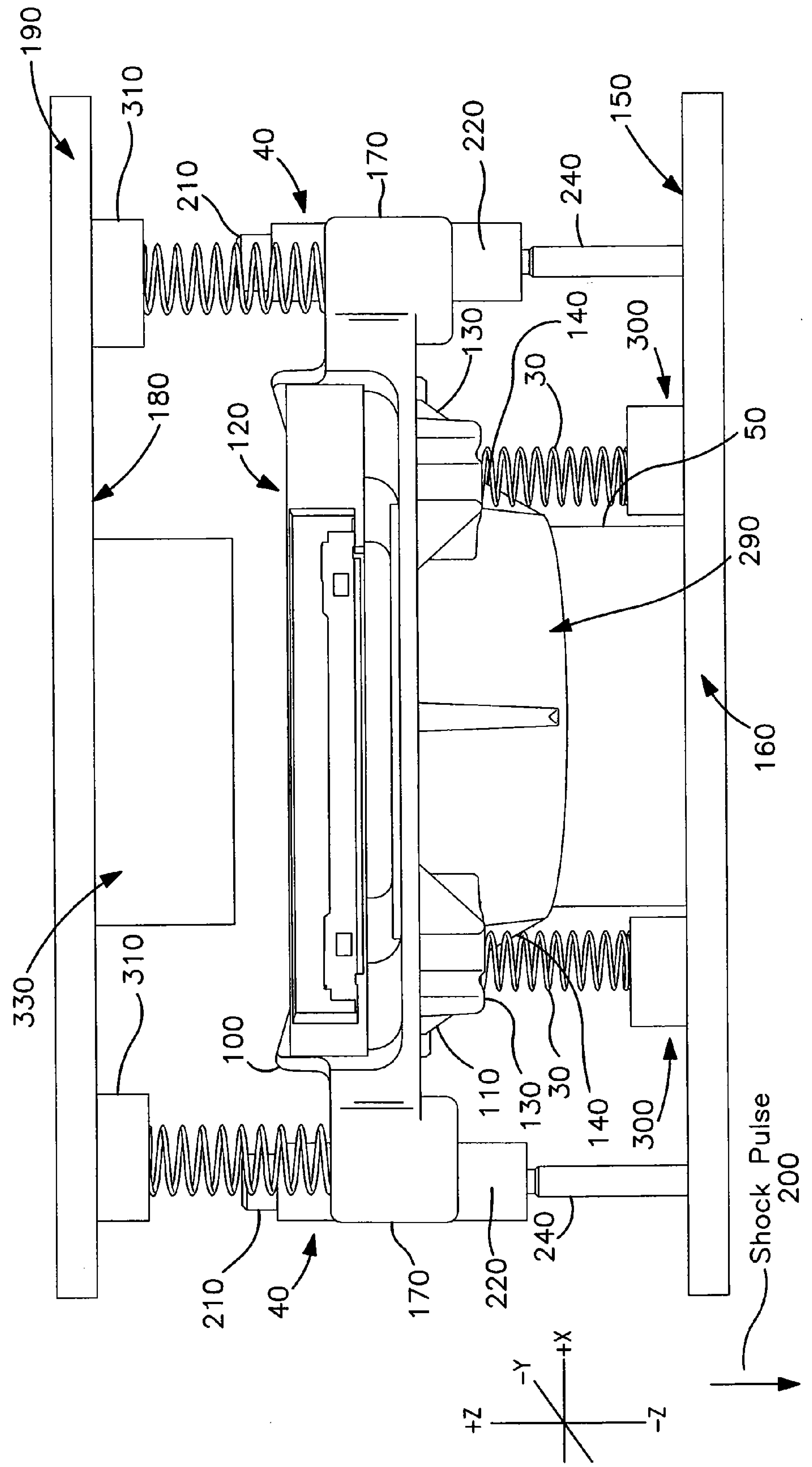

190
310
210
40
170
220
240
150
130
140
300
30
180
120
50
290
160
330
100
110
Shock Pulse
200
+Z
-Z
+X
-Y

FIG. 4

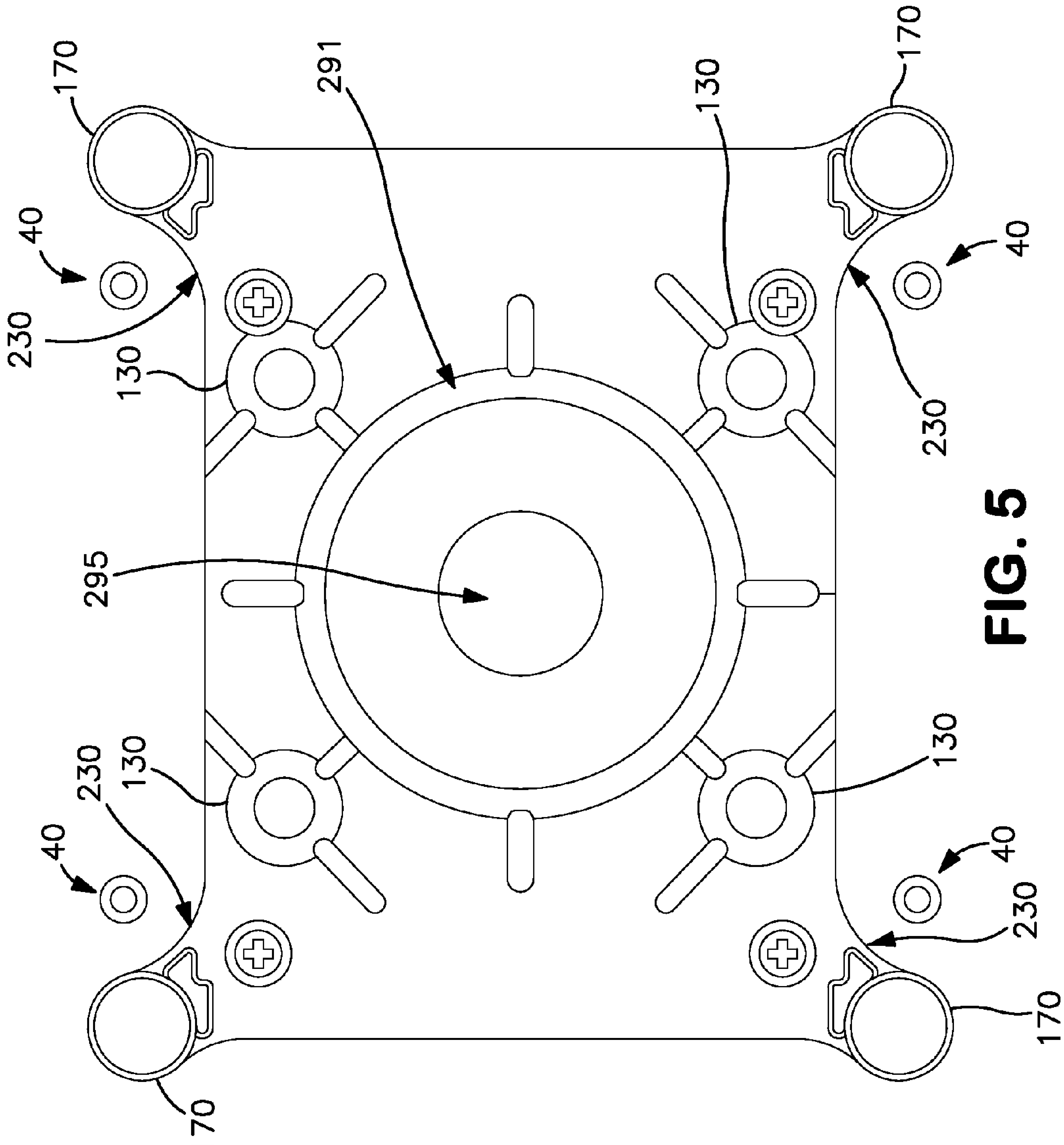

170
291
130
170
40
40
230
130
230
295
230
130
130
40
40
230
170
170

FIG. 5

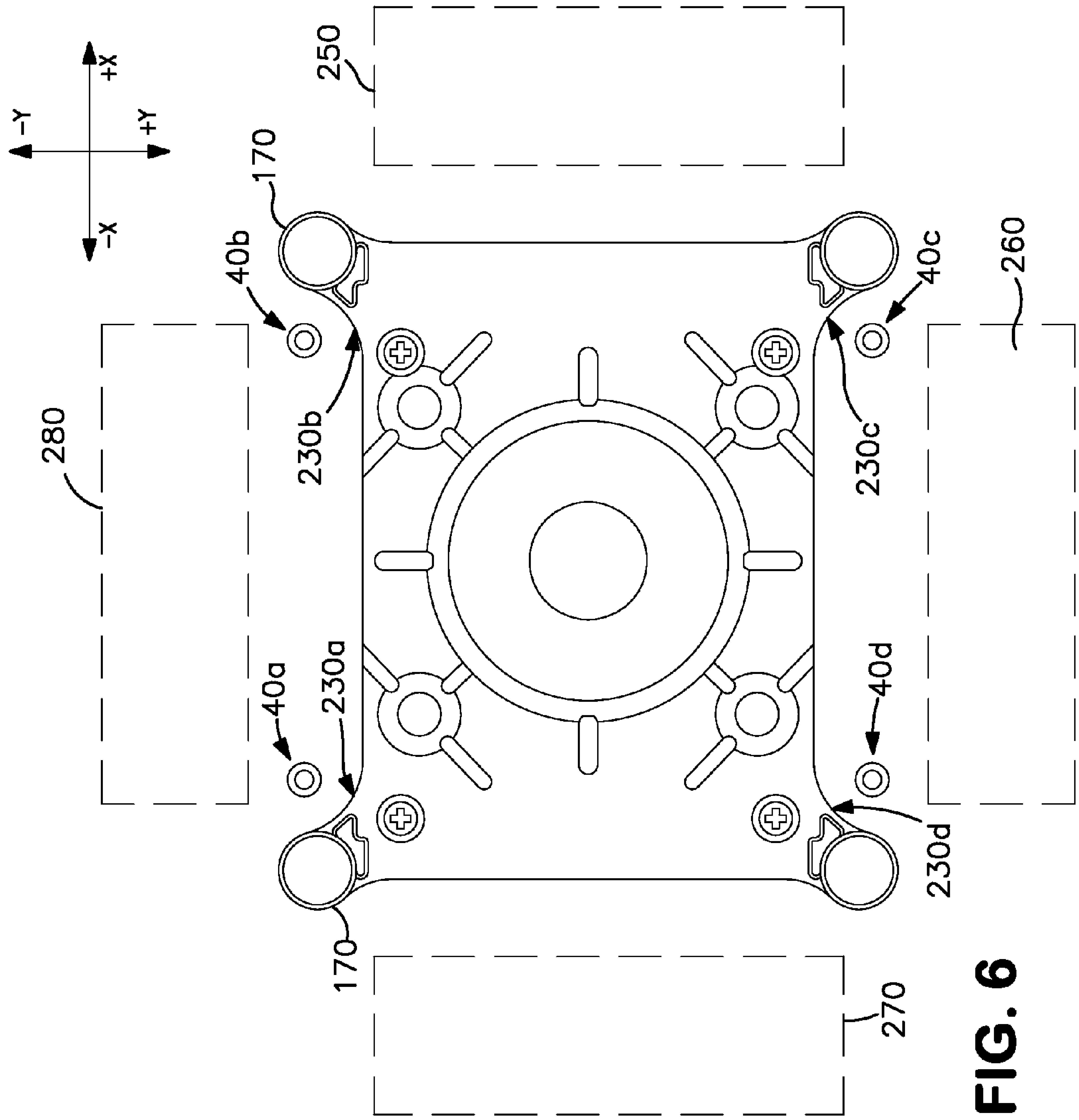

+X
−Y
+Y
−X
250
170
40b
40c
260
280
230b
230c
40a
230a
40d
230d
170
270

FIG. 6

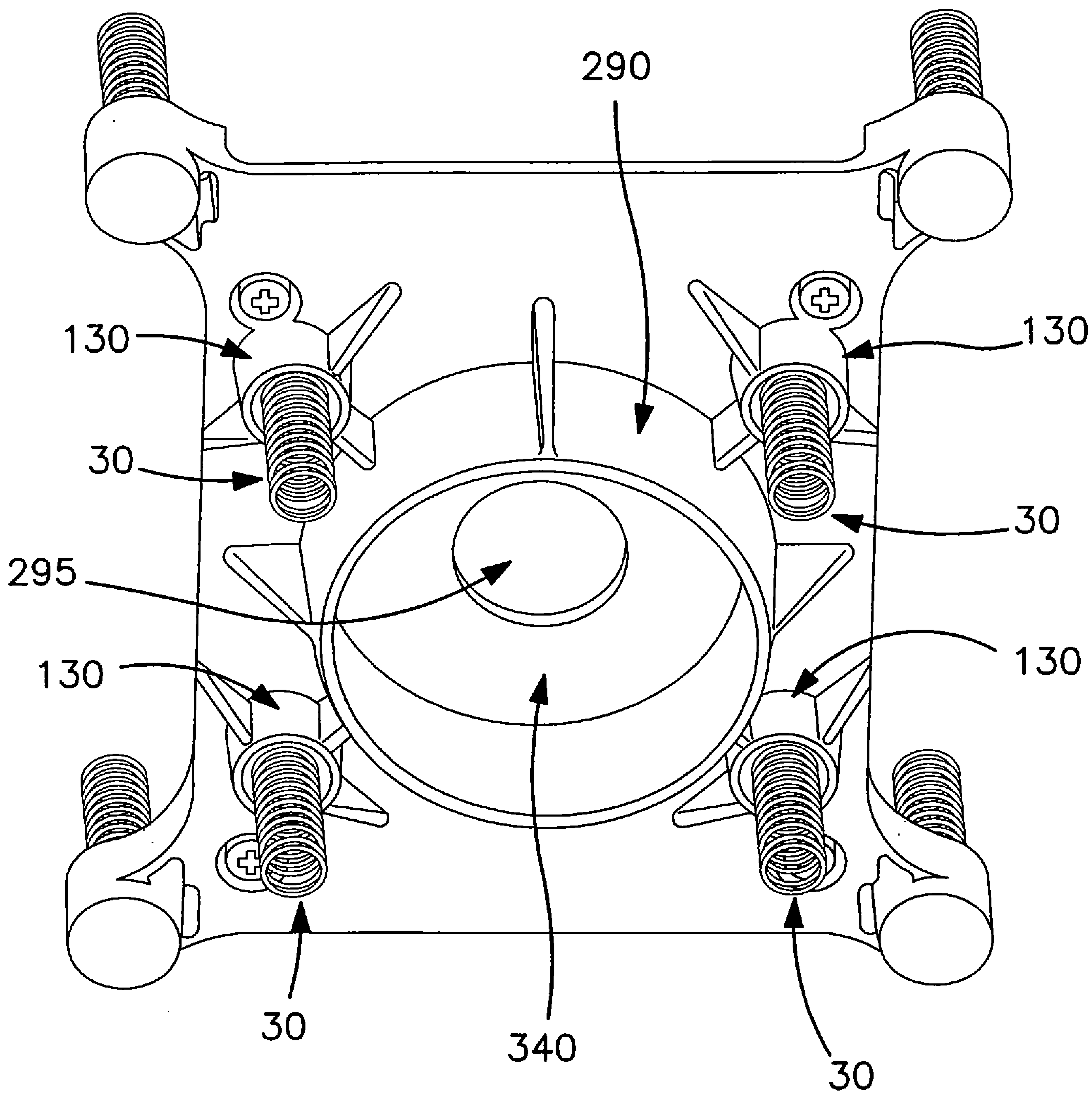


FIG. 7

VIBRATION ISOLATING DEVICE

FIELD OF THE INVENTION

This invention relates generally to vibration-reducing techniques, and more particularly, to a device for isolating an object from vibrations and/or shocks, and further, for protecting other object(s) in a vicinity of the object subjected to vibrations and/or shocks.

BACKGROUND

Mechanical hard drives, CD-ROMS, DVD-ROMS, etc. are some of examples of many objects that contain mechanically sensitive parts. When subjected to vibrations or shocks from external sources, such objects may suffer from a degraded performance or even a complete failure.

Often, vibration-sensitive objects are located within a larger system (e.g., a computer, a moving vehicle, a machinery, etc.), and thus become susceptible to vibrational disturbances and shocks external to the system or generated by other components within the system. More particularly, vibrations and/or shocks external to the system or generated by other components within a system itself could be transmitted to the object, potentially causing undesirable effects, such as performance degradation or a movement of the object.

In this regard, a sufficiently strong vibration or shock could displace the object to the point of "bumping" against other adjacent objects. Some shock or vibrations could be of such high magnitudes that damage to one or both of the objects may be inevitable.

Unfortunately, current vibration isolating systems may not be able to effectively isolate an object from external vibrations and/or shocks, and also minimize displacement of the object such as to protect system components from a potential damage.

SUMMARY

Advantageously, the present invention provides a vibration isolating device to isolate an object, such as a hard disk drive, from vibration and/or a shock that may come from an external source. Further, the vibration isolating device comprises features to protect the object and adjacent object(s) from damage that otherwise may result from a contact of the object with the adjacent object(s) in the presence of vibration and/or shock.

In one illustrative embodiment, the vibration isolating device comprises (i) a mounting structure having an area for mounting the object thereon, (ii) a plurality of first springs coupled to the mounting structure and operative to minimize coupling of the at least one vibration and shock to the object, (iii) a shock stop separate from the mounting structure comprising a first shock-absorbing material, and (iv) a plurality of stop pins separate from the mounting structure and arranged externally about the mounting structure, the plurality of stop pins operative to limit a displacement of the object when the at least one vibration and shock exceeds a given level. The vibration isolating device may further comprise a plurality of second springs that are operative to further minimize coupling of the at least one vibration and shock to the object.

These as well as other aspects and advantages will become apparent to those of ordinary skill in the art by reading the following detailed description, with reference where appropriate to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The device, in accordance with one or more embodiments, is described in detail with reference to the following drawings. The drawings are provided for purposes of illustration only and merely depict typical or example embodiments. These drawings are provided to facilitate the reader's understanding and shall not be considered limiting of the breadth, scope, or applicability of the disclosure. It should be noted that for clarity and ease of illustration these drawings are not necessarily made to scale.

FIG. **1** is a perspective view of the vibration isolating device in accordance with an embodiment of the present invention;

FIG. **2** is an end view of the vibration isolating device in accordance with an embodiment of the present invention;

FIG. **3** is a perspective view of the vibration isolating device in accordance with an embodiment of the present invention with an object installed thereon;

FIG. **4** is an end view of the vibration isolating device, including object **120** in accordance with an embodiment of the present invention;

FIG. **5** is a bottom view of the vibration isolation device in accordance with an embodiment of the present invention;

FIG. **6** is a bottom view of an embodiment of the vibration isolation device in proximity to adjacent objects; and

FIG. **7**. is a perspective view of the bottom of the vibration isolation device in accordance with an embodiment of the present invention.

Some of the figures included herein illustrate various embodiments from different viewing angles. Although the accompanying descriptive text may refer to such views as "top," "bottom" or "side" views, such references are merely descriptive and do not imply or require that the embodiment be implemented or used in a particular spatial orientation unless explicitly stated otherwise.

The figures are not intended to be exhaustive or limited to the precise form disclosed. It should be understood that the invention can be practiced with modification and alteration, and that it is limited only by the claims and the equivalents thereof.

DETAILED DESCRIPTION

FIG. **1** illustrates a perspective view of a vibration isolating device **10** according to one illustrative embodiment. As shown in FIG. **1**, vibration isolating device **10** generally includes a mounting structure **20**, a plurality of first springs, such as bottom springs **30**, coupled to mounting structure **20**, and stop pins **40** and shock stop **50** that are separate from the mounting structure and arranged externally to the mounting structure.

Bottom springs **30** and shock stop **50** are shown in more detail in FIG. **2** depicting a side view of the vibration isolating device of FIG. **1**. As shown in FIGS. **1** and **2**, in some embodiments, vibration isolating device **10** may further include a plurality of second springs, such as top springs **60**, coupled to the mounting structure and disposed in a direction opposite from the plurality of first springs, such as bottom springs **30**.

As shown in FIG. **2**, mounting structure **20** may include a top portion **70** and a bottom portion **80**. An object to be isolated from a vibration and/or shock may be mounted onto an area within the top portion **70** of the mounting structure. More specifically, as shown in FIG. **1**, top portion **70** may include a flat rectangular base **90** onto which the object could be mounted. In this regard, the size/surface area of base **90** may be adjusted accordingly to accommodate a particular object. As shown, each of the top springs **60** and bottom springs **30** is arranged substantially perpendicular to base **90** of the mounting structure.

Further, top portion **70** may include side walls **100** to secure the object, and in some embodiments, may also include side portions **110** (shown in FIG. **2**), that in combination with side walls **100**, may further secure the object within the mounting structure. In addition, the object could be attached to top portion **70** by other means, such as screws for example. It should be understood that mounting structure **20** is not confined to a rectangular form and could take other forms as well.

FIGS. **3** and **4** illustrate respectively the embodiments of FIGS. **1** and **2**, including an object **120**. For example, object **120** could be a mechanical hard disk drive (e.g., an HDD), such as shown in FIG. **4**. However, in other embodiments, vibration isolating device **10** may be used to provide vibration and shock isolation for a variety of other objects, examples of which include a DVD-ROM, a CD-ROM, an optics assembly, a laser assembly, a solid state drive, and an LCD assembly.

As shown in FIG. **3**, object **120** may be mounted or attached to base **90**, where the size of base **90** and side walls **100** may be adjusted to the size of object **120**, such as to securely hold the object in place. FIG. **4** shows an end view of object **120**, with side portions **110** that further secure the object within mounting structure **20**. Such arrangement may assist in holding the object in place more securely, in the event object **120** becomes loosened when subjected to high vibrations and/or shocks.

In general, vibration isolating device **10** may be provided to protect object **120** when the object is subjected to a vibration and/or shock from an external source. Object **120** could be a standalone object or a component of a larger system. Typically, object **120**, such as a hard disk drive for example, would be placed in a larger system (e.g., a computer). As such, any vibrations and/or shocks applied externally to or experienced by the system, or alternatively, generated by other components within a system itself (e.g., a 60 Hz or 120 Hz noise signals from a power supply, etc.) could be transmitted, or coupled, to object **120**.

Such vibration or other external forces may cause undesirable effects, such as a mechanical disturbances within object **120** or a movement of the object. Particularly, when subjected to vibration and/or shock, object **120** could be displaced such as to come into contact with other adjacent, or neighboring, objects. Depending on the amplitude (or magnitude) of a vibration or shock, the displacement of the object could be substantial, leading to an impact with another object and possible damage to either one of the objects.

In one illustrative embodiment, vibration isolating device **10** provides a number of features to provide isolation from external vibrations and/or shocks to the object **120**. In addition, some features of the vibration isolating device **10** may also provide damage protection to adjacent objects and/or object **120** that could otherwise result from contact between objects in the presence of vibration or shock.

In one aspect, vibration isolating device **10** comprises bottom springs **30**, coupled to mounting structure **20**. As shown, for example, in FIGS. **3** and **4**, bottom springs **30** may be coupled to bottom portion **80** of the mounting structure, and may be operative to minimize coupling, or transmission, of a vibration and/or shock to object **120**. In one embodiment, vibration isolating device **10** comprises four bottom springs. Each of the bottom springs **30** may include a coil compression spring, such as any suitable helical compressions spring (e.g., a COTS helical compression spring). Further, each of the bottom springs **30** may be coupled to mounting structure **10** via a spring holder **130**. Preferably, bottom springs **30** will be arranged such as to substantially equally load each of the bottom spring. As shown in FIGS. **3** and **4**, each of spring holders **130** is preferably an integral part of mounting structure (e.g., formed in the same mold as the mounting structure). However, each of spring holders **130** may also be a separate part coupled to the mounting structure **20** by means such as welding, bolting, etc.

It should be noted that one benefit of coupling bottom springs **30** via holders **130** is that the holders may help to stabilize each spring and limit deflection and sideways motion of the spring during vibration and/or shock. In this regard, the depth of each spring holder may be adjusted based on a given application and/or anticipated magnitude of vibrational/shock disturbance. Note that bottom portion **80** of mounting structure **20** may be shaped accordingly to accommodate spring holders **130** and provide clearance for the bottom springs. As shown in the example of FIG. **4**, bottom portion **80** of the mounting structure **20** could have, for example, a basin-like shape with slanted sides **140**.

Note, however, that it may be possible to couple bottom springs **30** to mounting structure **20** in other ways, such as through the use of suitable spring mounts, snubbers, and the like.

Bottom springs **30** may be disposed on any suitable support or bearing surface. Preferably, bottom springs **30** will be mounted such that mounting structure **20** is substantially leveled. In one embodiment, as shown in FIGS. **3** and **4**, bottom springs **30** are mounted within bottom mounting cups **300** which are disposed onto a surface **150** adjacent to object **120**, such as an adjacent object **160** sitting below object **120**. Generally, the ends of helical compression springs **30** are not attached to bottom cups **300** and springs **30** just "sit" within the bottom mounting cups **300** on surface **150**. Alternatively, the spring could be attached to the surface via any suitable means to hold the spring in place.

In an illustrative embodiment, bottom springs **30** may operate to "absorb" external vibrational and shock excitations to minimize transmission of such excitations to object **120**, and thus to isolate object **120** from such excitations. Further, bottom springs **30** may prevent object **120** from contacting other objects, such as adjacent object **160**.

In general, vibration isolation is a function of transmissibility, and is expressed as a percent ($I=(1-T)*100$)), where transmissibility denotes a ratio of a force transmitted to an object and an input force. Minimizing the amount of vibrations and/or shocks transmitted to object **120** will maximize the isolation. To achieve a desired amount of isolation, various spring parameters may be calculated/selected accordingly.

In particular, parameters, such as a spring stiffness (or spring rate), spring diameter, wire diameter, wire material, wire end conditions and spring-free length, etc., may be computed and/or adjusted accordingly to meet specific isolation design criteria and also to maximize spring life for various load conditions, anticipated vibration/shock conditions, etc. The parameters for spring selection can be based on well known formulas familiar to those skilled in the art. To avoid system failure resulting from improper selection of springs, spring factors for each of the springs in the system should be solved simultaneously. Those skilled in the art will appreciate that various available spring simulation or calculation tools could be used for this purpose.

Although bottom springs **30** may be able to provide a certain degree of isolation, the present invention provides additional features to further isolate object **120** from vibrations and/or shocks. In particular, as noted above, vibration isolating device **10** may further comprise second springs **60**, as shown in FIGS. **3** and **4** for example, that are disposed in a direction opposite from bottom springs **30**.

In particular, as shown in FIGS. **3** and **4**, second springs **60** may be coupled to top portion **70** of mounting structure **20**, such as at respective four corners of base **90**. Top springs **60** may be operative to further minimize coupling, or transmission, of external vibration and/or shock to object **120**, and generally, to further stabilize the object. In one embodiment, vibration isolating device **10** may comprise four top springs **60**.

Like bottom springs **30**, each of top springs **60** may include a coil compression spring, such as any suitable helical compressions spring (e.g., a COTS helical compression spring). Further, each of the top springs may be coupled to mounting structure **20** via a spring holder **170**. Similarly, as shown in FIG. **4** each top spring **60** will held in place on the top end by upper spring cup **310**. In one example, spring cup **310** is mounted to surface **180** of another object adjacent to object **120**, such as an adjacent object **190** sitting above object **120**, as shown.

As also shown in FIGS. **3** and **4**, each of spring holders **170** will preferably be an integral part of mounting structure **20** (e.g., formed in the same mold as the mounting structure). However, each of spring holders **170** could also be a separate part coupled to the mounting structure by any known means, such as welding or bolting. Likewise, spring cups **300** and **310** may form an integral part of objects **160** and **190** respectively, or could be mounted to the surfaces **150** and **180** of objects **160** and **190** by other means.

One benefit of coupling top springs **60** via holders **170** is that the holders may help to stabilize each spring and limit deflection and sideway motion of the spring during vibrations and/or shocks. In this regard, a depth of each spring holder may be adjusted based on a given application and/or anticipated level of vibrational/shock disturbance.

It should be noted that while top springs **60** and bottom springs **30** do not need to be attached to adjacent surfaces **180** and **150** respectively, to provide isolation they do need to remain within spring cups **300** and **310**. It is understood therefore, that spring cups **300** and **310** must be of sufficient depth to ensure that displacement in the ±z direction due to shock or vibration does not result in springs **30** or **60** falling out of their respective spring cups. Furthermore it is understood that the spring cups **300** and **310** can not be too deep to ensure that they do not contact spring holder cups **130** and **170** respectively during operation. Furthermore as described below with respect to shock stop **50** the depths of spring cups **300** and **310** must be sized according to the maximum expected displacement to avoid the springs from coming loose during a large displacement.

Indeed, when device **10** is oriented as shown in FIG. **4**, the forcing frequency (vibration input) is in the +z and −z axis. Top springs **60** are advantageously mounted such that they do not ever contact object **190** or surface **180** while still remaining within spring cups **310**. In fact, it has been shown that if the top springs are allowed to contact surface **180**, the forcing frequency increases in amplitude greatly. However, when the forcing frequency is not directly in the +z and −z axis, then the top springs **60** act to supply isolation functionality along with the bottom springs **30**. This lateral loading of the isolator results in a completely different spring rate required to effectively isolate whatever device is mounted to mounting structure **20** since the springs are not in a compression state but rather bending. Isolator **10** allows upper and lower springs **60** and **30** to bend or buckle, providing the equivalent spring force to springs in compression. It should be apparent to one skilled in the art, that the bending and compression factors must be accounted for and considered simultaneously so as not to have a spring failure due to excessive bending stress in the spring wire.

Further, top springs **60** may further limit displacement of object **120** and prevent object **120** from contacting other objects, such as adjacent object **190**, in the presence of external vibrations and/or shocks. The combination of top springs **60** and bottom springs **30** effectively minimize displacement of the object **120** in both vertical, horizontal, and lateral directions when subjected to vibration and/or shock inputs along all six axes (i.e., ±x-axis, ±y-axis, and ±z-axis). Also, the combination of top springs **60** and bottom springs **30** may counteract any oscillations that could potentially develop in either the bottom or top springs.

When in use, isolating device **10** may be mounted in a variety of configurations and orientations. Accordingly, the isolators must account for mounting the end device in any orientation, including upside down. As will be recognized, to achieve a desired amount of isolation, various spring parameters of top springs **60** and bottom springs **30** may be calculated/selected accordingly. In particular, parameters, such as a spring stiffness (or spring rate), spring diameter, wire diameter, wire material, wire end conditions and spring-free length, etc., may be computed and/or adjusted accordingly to meet specific isolation design criteria and also to maximize spring life for various load conditions, anticipated vibration/shock conditions, etc. Those skilled in the art will appreciate that various available spring simulation/calculation tools could be used for this purpose.

In a normal operation, the combination of top springs **60** and bottom springs **30** may be sufficient to isolate object **120** from a variety of vibrations of different frequencies and/or shocks transmitted from external source(s). However, the present invention recognizes that in some situations, object **120** could be subjected to external shock signals of sufficiently high amplitude/magnitude that may not be effectively reduced by bottom springs **30** an/or top springs **60**, and in effect, could be almost entirely or partially coupled to object **120**.

As noted above, vibration isolating device **10** works in conjunction with shock stop **50** and shock cup **290**. Shock stop **50** may be mounted to surface **150** of object **160** and extends perpendicularly upwards from surface **150** into shock cup **290** without contacting the sides of shock cup **290** or surface **340** of mounting plate **20**. In one embodiment, shock cup **290** is an integral part of mounting base **20** although it could be a separate component attached to mounting base **20** by one of several known means such as welding or screwing. Shock cup **290** extends in the −z-direction from surface **340** as indicated in FIG. **7** and is formed from protruding wall **291** shown in FIG. **5**. Shock cup **290** should be sufficiently large enough and deep enough to accommodate shock stop **50** without allowing it to contact the inner walls or surface **340**. Shock stop **50** may be coupled to any surface isolated from and opposite to a side on which object **120** is mounted. Shock stop **50** is preferably disk-shaped although other geometries, such as rectangular or oval may be used without impacting the effective ability of shock stop **50** to dampen shock or vibration. It should be further understood, however, that the geometry of shock stop **50** impacts the geometry of shock cup **290** and protruding wall **291** and care should be taken to ensure that the chosen geometries do not interfere with the isolation performance of device **10**.

Shock stop **50** is positioned adjacent to a central area of object **120** (or mounting structure **20**). In one embodiment, shock stop **50** is a disk having a surface area of at least 20% of a surface area of object **120**. The area of the shock stop is not a primary consideration, however, it does play a role and is a factor in the design but it can vary greatly based on the material used for the shock stop and with the amount of displacement that is allowable in the final mounting area of the full isolation system. Center-mounted shock stop **50** may essentially operate as a damping element to absorb, or dissipate, mechanical (kinetic) energy generated by shock excitation. The width and thickness or area size of the shock stop **50** varies depending on the material chosen and with the amount of displacement that is allowable in the final mounting area of the full isolation system.

In a normal operation, shock stop **50** will be coupled to surface **150** which is not in contact with isolator **10** or mounting structure **20**. Shock stop **50** extends into shock cup **290**, but does not contact surface **340** of mounting plate **20** or protruding wall **291** until acted on by an external vibration or shock that exceeds a given level, such as a particular signal amplitude or magnitude (e.g., at a particular vibration frequency) or an amount of force (e.g., a acceleration-based g-force (e.g., a ng/Hz input or ng^2/Hz random inputs).

By way of example, referring back to FIG. **4**, mounting structure **20** holding object **120** could sit above adjacent object **160**. Shock stop **50** is connected to surface **150** of object **160** and does not contact mounting structure **20** or surface **340** under normal operating conditions. If a shock pulse **200** of sufficiently high amplitude is applied to mounting structure **20** in the −z axis, bottom springs **30** will be compressed excessively, and the mounting structure could be displaced from its normal position in the −z direction.

In the absence of shock stop **50**, mounting structure **20** could contact with adjacent object **160**, potentially resulting in damage to both objects **160** and **120**. With shock stop **50** in place, however, mechanical energy caused by shock pulse **200** can be absorbed and dissipated by shock stop **50**. Thus, shock stop **50** essentially acts as a "buffer" between object **120** (or mounting structure **20** holding object **120**) and adjacent object **160** when the shock exceeds a given level in the −z direction, such as the level that cannot be effectively reduced by the springs.

FIG. **7** shows a perspective view of the bottom of an embodiment of isolator **10** with shock stop **50** omitted. The underside of surface **20** in this embodiment details integral spring cups **130**, shock cup **290**, opening **295** and surface **340** built into a single structure, while such integrated components may simplify assembly, it is to be understood, that isolator **10** can be comprised of component parts held together by any known means, such as welding, bolting, screwing, etc.

As shown in FIGS. **5** and **7**, mounting structure **20** may include an opening **295** in base structure **20**. Opening **295** may act to allow any heat generated by device **120** to dissipate. Mounting structure **20** also contains a protruding wall **291**. Protruding wall **291**, as shown in FIG. **5**, acts as the surrounding walls of shock cup **290**. Shock stop **50** is sized so as to not contact the inner walls of shock cup **290** or the surface **340** of mounting plate **20** in a normal state. It will be understood therefore, that the spacing between the walls of shock cup **290** and shock stop **50** serve as what is referred to as "sway space". The sway space allows isolator **10** to move freely so it can effectively isolate vibration. As will be appreciated by those skilled in the art, that as soon as any contact is made between isolator **10** and shock stop **50**, vibration isolation ceases to function correctly. Thus, the sway space is application specific to a large extent and can be tuned together with the rest of the system to come up with a desirable or allowable tolerances. The geometry of the shock stop is such that the sway space surrounding shock stop **50** and the distance between the top surface of shock stop **50** and surface **340** of mounting plate **20** are the same. Accordingly, the sway space distance in any combination of axis displacement due to shock is equal.

It should be understood therefore that the total potential displacement in the −z direction includes the space between the upper surface of shock block **50** (the "sway space") and surface **340** plus any compression of shock block **50** that may occur. This total potential displacement impacts the design depths of spring cups **310**. As will be understood by those skilled in the art, the depth of spring cup **310** must be greater then the total possible displacement in the −z direction to ensure that upper springs **60** do not dislocate from within spring cups **310** during displacement in the −z direction. Similarly, it will be further appreciated by those skilled in the art, that shock stop **50** can dampen and isolate shock in five of the six axes, it does not however, function to isolate shocks to isolator **10** in the +z direction as shown in FIG. **4**. An additional stop **330** may be placed above object **120** on the surface **180** the same distance away from the device to be isolated as the distance between surface **340** and the top surface of item **50**, thereby allowing for shock dampening equally in all six directions. Total possible displacement in the +z direction therefore is the distance between the bottom surface of stop **330** and the top of object **120** plus any compression of stop **330**. This distance, likewise impacts the design depth of spring cups **300**. Spring cups **300** must be deeper then the potential total displacement in the +z direction to ensure that springs **30** do not come loose during a maximum displacement in the +z direction. These distance, like the size of stop block **50** and shock cup **290**, are adjustable per application of the isolator.

In an embodiment, shock stop **50** includes material(s) with sufficiently high shock-absorbing properties. Examples of suitable shock-absorbing materials include, for example, materials having a Shore A or Shore D rating in the range of 0-70 Durometer. Suitable materials could be silicone, urethane, cellular gel, cellular foam, rubber, or any combinations thereof or any other suitable material with similar shock ratings.

In addition to stop shock **50**, vibration isolating device **10** will preferably comprise additional displacement-limiting features to limit displacement of object **120** in the presence of severe vibrations and/or shocks from external source(s). In particular, in an embodiment, vibration isolating device **10** comprises stop pins **40** that are separate from mounting structure **20** and arranged externally to the mounting structure **20**.

As shown in FIGS. **3** and **4**, for example, stop pins **40** are arranged externally to mounting structure **20**, such as around the perimeter of the mounting structure. As shown in FIG. **4**, each stop pin **40** may be adjacent to one respective top spring **60**, and may include one or more elongated members **210** and a stop portion **220**. Stop pins **40** are preferably directed substantially perpendicular to object **120** or base **90** of the mounting structure **20**. Further, one end, such as end **240**, of each of the stop pins may be held or attached in a place via any suitable means. The stop pins **40** may be press fit pins that are pressed into the housing (not shown) directly or screwed into the housing in which the isolator is installed. This is another variable based on the overall design as no two applications will have the same critical stop areas or available space for the stop pins **40** to be placed.

In a normal operation, mounting structure **20** holding object **120** will preferably not contact any of stop pins **40** until the vibration or shock exceeds a given level, such as a particular signal amplitude or magnitude (e.g., at a particular vibration frequency) or an amount of force (e.g., an acceleration-based g-force (e.g., a ng/Hz input or ng^2/Hz random inputs)).

Note that the given level at which stop pins **40** operate to limit a displacement of object **120** could be the same or different from a level at which shock stop **50** operates to limit the displacement of the object **120**. Preferably, the sway space associated with shock stop **50** and shock cup **290** is less then the displacement limits imposed by stop pins **40**.

As shown in FIG. **4**, each stop portion **220** could have a cylindrical shape although other shapes such as hexagonal or other geometries could be used. This feature helps to minimize contact surface area when mounting structure **20** holding object **120** comes in contact with any of stop pins **40**. Additionally, as noted above, each stop pin **40** may be adjacent to one respective top spring **60**, or its corresponding spring holder **170**. In this regard, as shown in FIGS. **3** and **5**, spring holders **170** or mounting structure **20** may have curved portions **230**.

One advantage of this feature is that when a contact occurs, the stop pin **40** may not only limit any further movement of object **120**, but may also allow mounting structure **20** to "slide" against the stop pin, preventing potentially undesirable jerks. Further, each stop portion **220** may comprise a shock-absorbing material such that the stop portion **220** may operate as a damping element to absorb, or dissipate, mechanical energy generated due to vibration or shock excitation when the contact occurs.

In this regard, each stop portion **220** will preferably include material(s) with sufficiently high shock-absorbing absorbing properties. Examples of suitable shock-absorbing materials include, for example, materials having a Shore A or Shore D rating in the range of 0-70 Durometer. Suitable materials could be silicone, urethane, cellular gel, cellular foam, rubber, or any combinations thereof or other materials with similar shock-absorbing properties.

In addition, the curved features of each of spring holders **170** may assist stop pins **40** in limiting a displacement of object **120**, such as along different axes of travel.

By way of example, referring to FIG. **6**, during vibration or a shock pulse of sufficiently high amplitude, stop pins **40*a*** and **40*b*** together with curve portions **230*a*** and **230*b*** could limit displacement of object **120** along −y axis to prevent contact with an adjacent object **280**. Stop pins **40*b*** and **40*c*** together with curve portions **230*b*** and **230*c*** could limit displacement of object **120** along −x-axis to prevent contact with an adjacent object **270**. Then, stop pins **40*c*** and **40*d*** together with curve portions **230*c*** and **230*d*** could limit displacement of object **120** along +y axis to prevent contact with an adjacent object **260**. Similarly, stop pins **40*d*** and **40*a*** together with curved portions **230*d*** and **230*a*** could limit displacement of object **120** along +x-axis to prevent contact with an adjacent object **250**. (Note that the above example is provided for illustration purposes only, and particular axis of orientation, directions of travel, etc. are only illustrative).

In effect, each curved portion **230** and adjacent stop pin **40** could operate to limit displacement of object **120** for two axes of travel. Further, in general, stop pins **40** could essentially act as a "buffer" between object **120** (or mounting structure **20** holding object **120**) and any adjacent object(s) when vibration and/or shock exceeds a given level, such as the level that cannot be effectively reduced by the springs. Note that spring holders **170** could be sized/shaped and spaced accordingly for a given application and/or anticipated magnitude of vibrational/shock disturbance. Similarly, stop pins **40**, which are independent from mounting structure **20**, could be arbitrarily sized (e.g. by selecting a given size of cylindrical stop portion **220**) and spaced around the mounting structure as well, such as based on a given application and/or anticipated magnitude of vibrational/shock disturbance. Further, in other embodiments, stop pins **40** could be shaped/structured in different ways from those described above.

The amount of force required for the isolator to contact the shock stop and/or the over stop pins is specific to each application of the isolator system as the mass of the system varies. In one example, the disclosed system was able to protect against both a 30G 18 ms and a 50G 11 ms shock pulse input.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not of limitation. Likewise, the various diagrams may depict an example architectural or other configurations and is intended to aid in understanding the features and functionality that can be included. The invention is not restricted to the illustrated example architectures or configurations, but the desired features can be implemented using a variety of alternative architectures and configurations. Indeed, it will be apparent to one of skill in the art how alternative functional, logical or physical partitioning and configurations can be implemented to implement the desired features of the present inventions.

Although, described in terms of various exemplary embodiments and implementations, it should be understood that the various features, aspects and functionality described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described, but instead can be applied, alone or in various combinations, to one or more of the other embodiments, whether or not such embodiments are described and whether or not such features are presented as being a part of a described embodiment. Thus the breadth and scope of the present disclosure should not be limited by any of the above-described exemplary embodiments.

Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing: the term "including" should be read as meaning "including, without limitation" or the like; the term "example" is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof; the terms "a" or "an" should be read as meaning "at least one," "one or more" or the like; and adjectives such as "conventional," "traditional," "normal," "standard," "known" and terms of similar meaning should not be construed as limiting the item described to a given time period or to an item available as of a given time, but instead should be read to encompass conventional, traditional, normal, or standard technologies that may be available or known now or at any time in the future. Likewise, where this document refers to technologies that would be apparent or known to one of ordinary skill in the art, such technologies encompass those apparent or known to the skilled artisan now or at any time in the future.

A group of items linked with the conjunction "and" should not be read as requiring that each and every one of those items be present in the grouping, but rather should be read as "and/or" unless expressly stated otherwise. Similarly, a group of items linked with the conjunction "or" should not be read as requiring mutual exclusivity among that group, but rather should also be read as "and/or" unless expressly stated otherwise. Furthermore, although items, elements or components of the invention may be described or claimed in the singular, the plural is contemplated to be within the scope thereof unless limitation to the singular is explicitly stated.

As will become apparent to one of ordinary skill in the art after reading this document, the illustrated embodiments and their various alternatives can be implemented without confinement to the illustrated examples. For example, the diagrams and their accompanying descriptions should not be construed as mandating a particular architecture, geometry or configuration.

What is claimed is:

1. A vibration isolating device for isolating an object from at least one of vibration and shock from an external source, comprising:

- a mounting structure having an area for mounting the object thereon;
- a plurality of first springs coupled to the mounting structure and operative to minimize coupling of the at least one vibration and shock to the object;
- a shock stop comprising a first shock-absorbing material in proximity to a side of the mounting structure opposite to the object and operative to limit a first displacement of the object when the at least one vibration and shock exceeds a first given level;
- a shock cup attached to the mounting structure, wherein the shock stop extends into the shock cup such that a sway space is established between walls of the shock cup and surfaces of the shock stop; and
- a plurality of stop pins separate from the mounting structure and arranged externally about the mounting structure, the plurality of stop pins operative to limit a second displacement of the object when the at least one vibration and shock exceeds a second given level, wherein each of the stop pins includes a second shock-absorbing material.

2. The device of claim **1**, further comprising a plurality of second springs operative to further minimize coupling of the at least one vibration and shock to the object.

3. The device of claim **2**, wherein the mounting structure has a top portion and a bottom portion, and wherein the first springs are coupled to the bottom portion, and the second springs are coupled to the top portion.

4. The device of claim **2**, wherein each of the first springs and each of the second springs includes a helical compression spring.

5. The device of claim **1**, wherein each of the first springs has one end that abuts or is attached to a surface of an adjacent object.

6. The device of claim **2**, wherein each of the second springs has one end that abuts or is attached to a surface of an adjacent object.

7. The device of claim **1**, wherein each of the first springs has one end that is housed in a mounting device that is attached to a surface of an adjacent object.

8. The device of claim **2**, wherein each of the second springs has one end that is housed in a mounting device that is attached to a surface of an adjacent object.

9. The device of claim **2**, wherein each of the first and second springs is substantially perpendicular to the area of the mounting structure on which the objected is mounted.

10. The device of claim **1**, wherein each of the first springs is coupled to the mounting structure via a spring holder, and wherein the spring holder is a part separate from the mounting structure or an integral part of the mounting structure.

11. The device of claim **2**, wherein each of the second springs is coupled to the mounting structure via a spring holder, and wherein the spring holder is a part separate from the mounting structure or an integral part of the mounting structure.

12. The device of claim **2**, wherein the mounting structure is rectangular and the second springs are disposed around the mounting structure at four corners.

13. The device of claim **2**, wherein the plurality of first springs is four first springs, and wherein the plurality of second springs is four second springs.

14. The device of claim **1**, wherein the shock stop is operative to limit the first displacement of the object when the at least one vibration and shock exceeds the second given level that is same or different from the first level.

15. The device of claim **1**, wherein the first shock absorbing material has a Shore A or Shore D rating of 0-70 Durometer.

16. The device of claim **1**, wherein the first shock absorbing material is selected from the group consisting of silicone, urethane, cellular gel, cellular foam, rubber, and combinations thereof.

17. The device of claim **14**, wherein the shock stop is connected to an adjacent object and does not come into contact with the mounting structure until the at least one vibration and shock exceeds the second given level.

18. The device of claim **1**, wherein the second given level is greater than the first given level.

19. The device of claim **1**, wherein the second shock absorbing material has a Shore A or Shore D rating of 0-70 Durometer.

20. The device of claim **1**, wherein the second shock absorbing material is selected from the group consisting of silicone, urethane, cellular gel, cellular foam, rubber, and combinations thereof.

21. The device of claim **1**, wherein the plurality of stop pins is four stop pins.

22. A vibration isolating device for isolating an object from at least one of vibration and shock from an external source, comprising:

- a mounting structure having an area for mounting the object thereon;
- a plurality of first springs coupled to the mounting structure and operative to minimize coupling of the at least one vibration and shock to the object;
- a shock stop comprising a first shock-absorbing material in proximity to a side of the mounting structure opposite to the object and operative to limit a first displacement of the object when the at least one vibration and shock exceeds a first given level;
- a shock cup attached to the mounting structure, wherein the shock stop extends into the shock cup such that a sway space is established between walls of the shock cup and surfaces of the shock stop;
- a plurality of stop pins separate from the mounting structure and arranged externally about the mounting structure, the plurality of stop pins operative to limit a second displacement of the object when the at least one vibration and shock exceeds a second given level; and
- a plurality of second springs operative to further minimize coupling of the at least one vibration and shock to the object, wherein each stop pin is adjacent to the respective one of the plurality of second springs.

23. A vibration isolating device for isolating an object from at least one of vibration and shock from an external source, comprising:

- a mounting structure having an area for mounting the object thereon;
- a plurality of first springs coupled to the mounting structure and operative to minimize coupling of the at least one vibration and shock to the object;
- a shock stop comprising a first shock-absorbing material in proximity to a side of the mounting structure opposite to the object and operative to limit a first displacement of the object when the at least one vibration and shock exceeds a first given level;

a shock cup attached to the mounting structure, wherein the shock stop extends into the shock cup such that a sway space is established between walls of the shock cup and surfaces of the shock stop;

a plurality of stop pins separate from the mounting structure and arranged externally about the mounting structure, the plurality of stop pins operative to limit a second displacement of the object when the at least one vibration and shock exceeds a second given level; and

wherein each of the first springs is coupled to the mounting structure via a spring holder, wherein the spring holder is a part separate from the mounting structure or an integral part of the mounting structure, and wherein each spring holder has a curved portion, and wherein each stop pin is adjacent to a curved portion of a respective spring holder.

24. The device of claim **23**, wherein each of the plurality of stop pins in combination with the respective curved portion limits the second displacement of the object along two axes of motion.

25. A vibration isolating device for isolating an object from at least one of vibration and shock from an external source, comprising:

a mounting structure having an area for mounting the object thereon;

a plurality of first springs coupled to the mounting structure and operative to minimize coupling of the at least one vibration and shock to the object;

a shock stop comprising a first shock-absorbing material in proximity to a side of the mounting structure opposite to the object and operative to limit a first displacement of the object when the at least one vibration and shock exceeds a first given level;

a shock cup attached to the mounting structure, wherein the shock stop extends into the shock cup such that a sway space is established between walls of the shock cup and surfaces of the shock stop;

a plurality of stop pins separate from the mounting structure and arranged externally about the mounting structure, the plurality of stop pins operative to limit a second displacement of the object when the at least one vibration and shock exceeds a second given level; and

wherein the mounting structure has a plurality of curved portions, and wherein each stop pin is adjacent to a respective one of the plurality of curved portions.

26. The device of claim **25**, wherein each of the plurality of stop pins in combination with the respective curved portion limits the second displacement of the object along two axes of travel.

* * * * *